Effect of Hot Water Surface Pasteurization of Whole Fruit on Shelf Life and Quality of Fresh-Cut Cantaloupe

X. FAN, B.A. ANNOUS, J.C. BEAULIEU, AND J.E. SITES

ABSTRACT: Cantaloupes are associated with recent outbreaks of foodborne illnesses and recalls. Therefore, new approaches are needed for sanitization of whole and cut fruit. In the present study, whole cantaloupes were submerged into water in the following 3 conditions: 10 °C water for 20 min (control), 20 ppm chlorine at 10 °C for 20 min, and 76 °C water for 3 min. Populations of microflora were measured on the rinds of the whole cantaloupes. Quality and microbial populations of fresh-cut cantaloupes prepared from whole fruit were analyzed after 1, 6, 8, 10, 13, 16, and 20 d of storage at 4 °C. The hot water significantly reduced both total plate count (TPC) and yeast and mold count on rind of whole fruits while chlorine or cold water wash did not result in a significant reduction of microbial population. Fresh-cut pieces prepared from hot water-treated cantaloupes had lower TPC than the other 2 treatments in the later storage periods (days 13 to 20) in 2 of 3 trials. The hot water treatment of whole fruits was inconsistent in reducing yeast and mold count of fresh-cut pieces. Soluble solids content, ascorbic acid content, fluid loss, and aroma and appearance scores were not consistently affected by either hot water or chlorine treatment. Our results suggested that hot water pasteurization of whole cantaloupes frequently resulted in lower TPCs of fresh-cut fruit during storage and did not negatively affect quality of fresh-cut cantaloupes.

Keywords: cantaloupe, chlorine, hot water, microbial populations, quality

Introduction

Consumption of fresh produce has been linked to outbreaks of foodborne illness and recalls in the United States due to contamination with human pathogens. Of these produce-related outbreaks, 25% were associated with fresh-cut produce (Smith 2006; Smith, personal communication). Pathogens, when present on the surface of whole fruits or vegetables, can be transferred to the fresh-cut produce during processing (cutting, peeling, and so on). Melons (mostly cantaloupes) are one of the groups of produce that are most frequently associated with outbreaks and contamination with foodborne pathogens (USFDA 2001b, 2003). Between 1990 and 2000, more than 700 cases of salmonellosis were reported in the United States and Canada (USFDA 2001a). The high rates of pathogen contamination associated with melon highlight the need for effective interventions for both whole and cut melons.

Over the last decade, many chemical antimicrobials have been investigated for their effectiveness against human pathogens. However, most chemical interventions have limited effectiveness for reducing the microbiological population on the surface of cantaloupes (Sapers and others 2001; Ukuku and others 2004a), partially due to the rough surface (netting) that provides a protective environment to microbes.

Certain hot water treatments have been shown to effectively reduce human pathogens and native microflora on whole cantaloupes (Annous and others 2004; Solomon and others 2006). Ukuku and others (2004b) demonstrated that immersion of inoculated cantaloupe in hot water or 5% hydrogen peroxide solution at 70 °C for 1 min resulted in up to a 3.8 log CFU/cm^2 reduction in *Salmonella*. Annous and others (2004) reported that surface pasteurization with hot water at 76 °C for 3 min resulted in more than 5 log CFU/cm^2 reduction in *S. enterica serovar* Poona and *Escherichia coli* populations with inoculated cantaloupes. In our previous study (Fan and others 2006), we demonstrated that hot water treatment in combination with low dose gamma radiation further reduced microflora of fresh-cuts compared to hot water or irradiation alone, and had no significant effect on the quality of fresh-cuts during 7−d storage at 4 °C. However, it is unclear whether hot water treatment of whole fruit will have any significant effect on the quality of fresh-cut cantaloupe during prolonged storage. Therefore, the objective of this study was to investigate the effect of hot water treatment, in comparison with chlorine treatment, of whole cantaloupe on the indigenous microbial population and quality of fresh-cut fruit during 20-d storage at 4 °C.

Materials and Methods

Cantaloupes

Cantaloupes (*Cucumis melo* L. var. *cantalupenis Naud*) of Costa Rican origin were obtained from a major fruit company. The studies were repeated 3 times during a 3-mo period. Cultivars were 'Torreon' for the 1st 2 trials and 'Hymark' for the last run. Fruit with bruising and compression damage as well as overripe fruit were discarded. The fruits were stored at 4 °C for no more than 2 d before treatments. The average weight of each fruit was 1535 g (1st trial),

MS 20070270 Submitted 4/13/2007, Accepted 1/18/2008. *Authors Fan, Annous, and Sites are with Eastern Regional Research Center, Agricultural Research Service, U.S. Dept. of Agriculture, 600 East Mermaid Lane, Wyndmoor, PA 19038, U.S.A. Author Beaulieu is with Southern Regional Research Center, Agricultural Research Service, U.S. Dept. of Agriculture, 1100 Robert E. Lee Blvd. New Orleans, LA 70124, U.S.A. Direct inquiries to author Fan (E-mail: xuetong.fan@ars.usda.gov).*

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Dept. of Agriculture.

doi: 10.1111/j.1750-3841.2008.00695.x

1059 (2nd trial), and 1394 g (3rd trial). The variation in the size of melons may reflect the differences in cultivar and growing conditions during the 3-mo period.

Treatment of whole fruit

The cold (6 to 7 °C) whole cantaloupes were subjected to the following 3 treatments: submerged in cold water (10 ± 0.2 °C) for 20 min, 20 ppm chlorine (pH 6.5 adjusted with citric acid) solution at 10 ± 0.2 °C for 20 min, and hot (76 ± 0.2 °C) water for 3 min. The chlorine treatments simulated current practice of many fresh-cut companies where fruits and vegetables were sanitized with 15 to 20 ppm chlorine for a long time (more than 10 min) in a cold produce processing plant. The treatments were conducted in a commercial size (325 L) processing vessel system developed by ERRC. The system was equipped with rapid refrigeration and heating capability, which was controlled by a Programmable Logic Controller from CAL Controls (Libertyville, Ill., U.S.A.). The temperature profile data were recorded with a personal computer equipped with custom application software developed at the USDA using the LabVIEW (Natl. Instruments, Austin, Tex., U.S.A.). The temperature profile and thermal penetration into different depths of the fruits have been reported (Solomon and others 2006). Individual cantaloupes were submerged under the water by a conveyor belt system, transported through the water tank, and emerged from the other end of the tank. Sets of 18 cantaloupes were treated for each trial. For cold water and hot water treatments, deionized water was added to the processing vessel and the water temperature was either lowered to 10 °C or heated to 76 °C. For the chlorine treatment, water was first cooled down to 10 °C, then bleach (6% sodium hypochlorite) was slowly added to the water and allowed to mix for approximately 45 min. After the solution had been mixed, 0.1 M solution of citric acid was added until the pH reached 6.5. The free chlorine level was measured using EM Science RQ Flex and ReflectoQuant P/N (EM Science, Gibbstown, N.J., U.S.A.) before the addition of the cantaloupes and during treatments. Free chlorine concentrations before cantaloupe addition were 17.6 ± 0.2, 17.1 ± 0.5, and 16.7 ± 0.7 ppm in trial 1, 2, and 3, respectively. At the end of trials 1, 2, and 3, chlorine concentrations were 17.1 ± 0.5, 16.2 ± 1.2, and 16.0 ± 1.6 ppm, respectively. After treatment, individual melons were immediately sealed in polyethylene zipperlock storage bags (S.C. Johnson and Sons Inc., Racine, Wis., U.S.A.) and submerged for 5 min in ice water. After 5-min immersion in ice water, fruit temperature at a depth of 5 mm was about 18 °C. Fresh-cut cubes were prepared from the cantaloupes as described subsequently.

Preparation of cantaloupe cubes

All preparations were conducted in a food processing cold room (8 °C) under strict sanitary conditions (Fan and others 2006). All utensils and equipment used for preparing fresh-cut pieces were sanitized by immersion in 300 ppm chlorinated water for 5 min. After the water treatment, the fruits were uniformly peeled using a mechanical fruit peeler as previously described (Annous and others 2004). The peeler was sanitized with 70% ethanol after each melon. The rind peels from the sets of 3 cantaloupes given each of the 3 treatments were saved and put into individual plastic bags for microbial analysis. Three nontreated (nonwashed) cantaloupes were also peeled for microbial analysis. The peeled melons were sliced once longitudinally, seeds were removed, and the seed cavity was cleaned manually. Halves were cut into approximately 2- to 3-cm slices, and cubes were prepared from the slices, as previously described (Beaulieu and Lea 2003). The average weights of the cubes were 20 ± 4, 16 ± 4, and 17 ± 3 g in trials 1, 2, and 3, respectively. Cubes of each replicate from 5 to 6 fruits were randomized, and placed into 16 oz polystyrene clamshell containers that were supplied by Del Monte Fresh Produce Co. (Coral Gables, Fla., U.S.A.). The amount of cut cantaloupes in each container was between 375 and 400 g. The volume of headspace in the clamshells containing cut cantaloupes was around 250 mL. All containers of fresh-cut cantaloupe were then stored at 4 °C for up to 20 d. As discussed subsequently, following 1, 6, 8, 10, 13, 16, 18, and 20 d of storage, samples were analyzed for appearance, aroma, firmness, color, soluble solids content, fluid loss, ascorbic acid content, and headspace O_2 and CO_2 within the packages. Cantaloupe rinds (from whole melons) and fresh-cut cubes were analyzed for total aerobic microorganisms, yeast, and mold.

Sampling protocols for total aerobic microorganisms

The rinds and fresh-cut samples (approximately 100 g) were combined with 0.1% peptone water (PW; BBL/Difco, Sparks, Md., U.S.A.) in ratio of a 3:1 and 1:1 respectively, and blended at medium speed for 1 min with commercial Waring blender Model 51BL31 (Waring Products, Torrington, Conn., U.S.A.). The resulting homogenate was filtered through a filter bag (Spiral Biotech, Bethesda, Md., U.S.A.), and duplicate 10-mL filtrate samples were transferred to sterile tubes. Filtrates were then diluted in PW as needed and surface plated on tryptic soy agar (TSA; BBL/Difco) or Yeast and Mold Petrifilm (3M, St. Paul, Minn., U.S.A.). TSA plates and Petrifilms were incubated at 35 °C for 24 h, and room temperature (19 ± 1 °C) for 5 d, respectively. Colonies were counted manually. The total plate count (TPC) and yeast mold count were expressed as log CFU/cm^2 of rind or per gram of fresh-cut cubes. The surface area of whole cantaloupes was calculated as previously described by Annous and others (2004).

Sensory evaluation

Sensory evaluation (visual quality and aroma) was conducted using a 9-point intensity scale (Bai and others 2001; Beaulieu 2005). For appearance, the description for the scale was 9 = excellent quality, essentially free from defects, fresh appearing; 7 = good quality, minor defects; slightly visible loss of orange color, not objectionable; 5 = pale color, fair, slightly to moderately objectionable defects (such as soggy edges), lower limit for sales appeal; 3 = poor, excessive defects, obvious pale/whitish discoloration, slimy surface on some cubes; 1 = extremely poor, not usable, mold, slimy. For aroma, 9 = strong, characteristic cantaloupe odor; 7 = pleasant, mild cantaloupe odor, slightly "flat"; 5 = bland, faint cantaloupe odor, detectable off-odor; 3 = mild sour or other off odors; 1 = distinct strong off-odor, fermented-like. Three judges who had extensive experience in evaluating fresh-cut cantaloupes independently performed the subjective assessments each sampling day.

Headspace atmosphere in packages

On each day of quality analysis, headspace samples (0.5 mL) were withdrawn from each of the 3 packages (per treatment) by piercing the unopened package using an airtight syringe. O_2 and CO_2 levels in the samples were then analyzed using a Gow−Mac Series 580 gas chromatograph (Gow−Mac Instrument, Bridgewater, N.J., U.S.A.) equipped with a 183 cm CTR I column (Alltech Associates Inc., Deerfield, Ill., U.S.A.) and a thermal conductivity detector. The CTR I column consists of an outer column (0.64 cm i.d.) packed with an activated molecular sieve and an inner column (0.32 cm i.d.) packed with a porous polymer mixture. The fruit pieces in the packages were then used for subsequent quality analysis.

Texture measurement

On each sampling day, 4 fresh-cut cubes from each replicate (package) were selected. Penetration tests were conducted on the cubes using a TA-XT2i Texture Analyzer (Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) as previously described (Fan and others 2005, 2006). Cubes were cut to achieve a leveled surface for texture analysis. A 6-mm-dia probe was used to penetrate the center of samples to a depth of 10-mm at a speed of 10 mm/s. Maximum force (kg) and area under the curves were recorded using the Texture Expert software version 1.22 (Texture Technologies Corp.).

Color analysis

Color was measured with a Hunter Miniscan XE colorimeter (Hunter Associates Lab, Reston, Va., U.S.A.) using a 1.9 cm measuring aperture. The colorimeter was calibrated using the standard white and black tiles. D65/10 ° was used as the illuminant/viewing geometry. Surface color of 4 cubes from each replicate of each treatment was measured; L^*, a^*, and b^* were recorded at 2 opposite sides of each cube. Measurements were made at the midpoint between the rind and core ends. Hue and chroma values were calculated with the following equations: hue $= \tan^{-1}(b^*/a^*)$ and chroma $= (a^{*2} + b^{*2})^{1/2}$.

Soluble solids content

Juice was extracted from cantaloupe cubes using a Champion MAR−48C juicer (Plastaket MFG Co., Lodi, Calif., U.S.A.). Soluble solid content in the juice was then measured using a hand-held refractometer at ambient temperature (approximately 23 °C).

Analysis of ascorbic acid

Ascorbic acid (AA) was measured according to Graham and Annette (1992) with minor modifications (Fan and others 2003). Samples (10 g) were homogenized with 20 mL 5% (62.5 mM) metaphosphoric acid (MPA) using a homogenizer (Virtishear, Virtis, Gardiner, N.Y., U.S.A.) at a speed setting of 70 for 1 min. The homogenate was filtered through 4 layers of cheesecloth, and then the filtrate was centrifuged at 12000 × *g* for 10 min at 5 °C in a Sorvall RC2-B refrigerated centrifuge (Kendro Laboratory Products, Newtown, Conn., U.S.A.). The supernatant was filtered through a 0.45 μm Acrodisc LC 13 PVDF syringe filter (Gelman Sciences, Ann Arbor, Mich., U.S.A.) before being analyzed using a Hewlett Packard Ti-series 1050 HPLC system (Agilent Technologies, Palo Alto, Calif., U.S.A.). The HPLC system consisted of an autosampler, an integral photodiode-array detector, an autoinjector, and a Hewlett-Packard Rev. A02. 05 Chemstation. Injection volume was 20 μL. Separation of compounds was achieved with an Aminex HPX-87H organic acids column (300 × 7.8 mm) fitted with a microguard cation H+ (Bio-Rad Laboratories, Hercules, Calif., U.S.A.) and eluted with a mobile phase of 5 mM sulfuric acid at a flow rate of 0.5 mL/min. Column temperature was maintained at 30 °C using a column heater (Bio-Rad Laboratories). Ascorbic acid was monitored at 245 nm and calculated from an AA standard curve.

Fluid loss

The overall weight of samples and amounts of juice accumulated in the clamshell containers of fresh-cut cantaloupes were measured. Percent fluid loss was calculated by dividing the weight of the juice with the overall initial product weight and multiplying by 100.

Statistical analysis

The whole experiment was repeated 3 times using cantaloupes from different sources during a period of 3 mo, resulting in 3 separate trials. For each trial, the experimental design was a randomized complete block design with 3 packages for each treatment/sampling day. Analysis of variance (ANOVA) was used to determine significant differences ($P < 0.05$) among population means in response to treatment and storage time. The least significant difference (LSD) test was used within storage times to test treatment effects and within treatment to test storage effect. All statistical analyses and calculations of means and standard deviations were performed by SAS software (SAS Inst. Inc., Cary, N.C., U.S.A.). Only significant difference ($P < 0.05$) was discussed unless otherwise described.

Results and Discussion

Changes in headspace composition during storage

O_2 levels in the containers decreased rapidly for all samples of the 3 trials during the 1st 6 d at 4 °C (Figure 1). At day 8, there was an unexpected surge in O_2 levels for the samples prepared from hot water- and chlorine-treated melons in trial 1, which may be due to

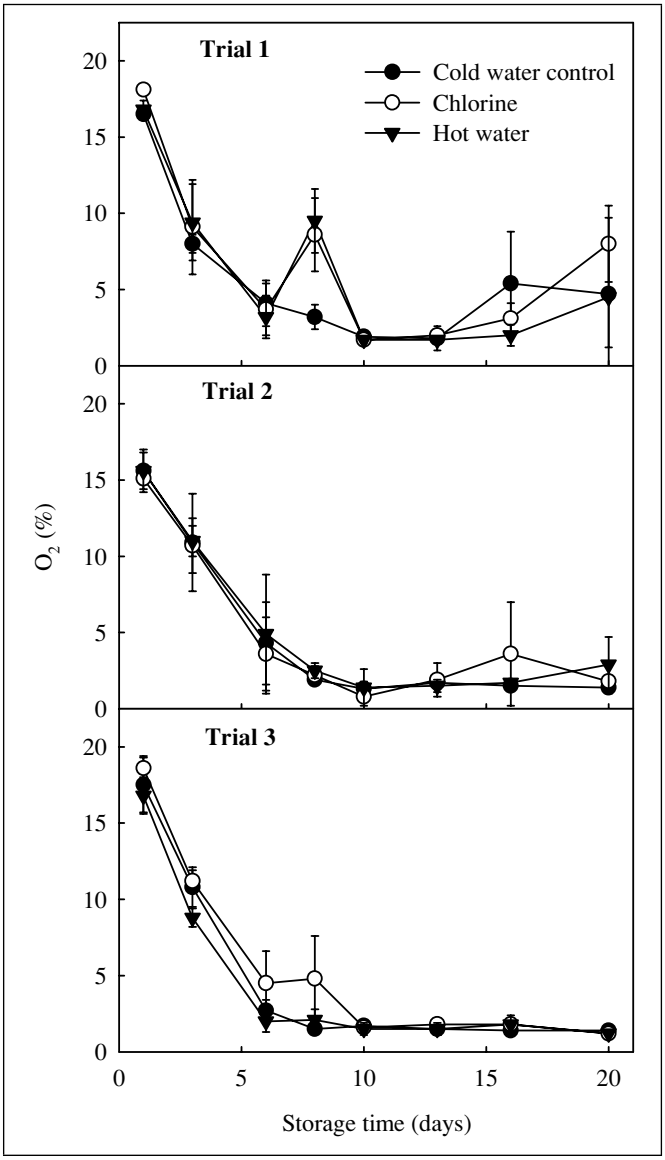

Figure 1 — Effects of hot water and chlorine treatment of whole cantaloupes on headspace O_2 levels in the packages of fresh-cut fruit during storage at 4 °C. Vertical bars represent standard deviations of means ($n = 3$).

sampling errors or leaks in the containers. At day 10, O_2 levels decreased to less than 2% for all samples. Afterward, O_2 levels slightly increased in the 1st trial, but had little change in the 2nd and 3rd trials. It is unclear why O_2 levels in the packages increased following a decrease. Perhaps the clamshell containers allowed very low levels of gas exchanges. In addition, respiration of cut cantaloupes might change during storage. Similar decreases and increases in O_2 levels in modified atmosphere packages of cut cantaloupes were observed by Boynton and others (2006) in 1 of 2 trials. The researchers attributed the changes to the increase in respiration rate of cut cantaloupe after 7 to 9 d of storage at 5 °C (Aguayo and others 2004). CO_2 levels increased continuously during storage, reaching levels of more than 10% after 10-d storage (Figure 2). At the end of 20 d, CO_2 levels were 15% to 25%, with lower levels observed in trial 2. There was no difference in the O_2 and CO_2 levels among the 3 treatments. The increases in CO_2 and decreases in O_2 in the containers are due to respiration of cut fruits. It seems that neither hot water nor chlorine treatment of whole cantaloupe significantly changed the physiology of whole and cut fruit. An earlier study (Luna-Guzman and Barrett 2000) found that treating fresh-cut cantaloupes in 2.5% calcium lactate at 60 °C for 1 min did not change the physiological behaviors of tissue and ethylene production, and respiration rates were not significantly affected. It has been shown that heat inhibited the ripening process of many fruits, resulting in lower respiration and ethylene production (Lurie 1998; Paull and Chen 2000). Lamikanra and others (2005) found that treating whole cantaloupes in 50 °C for 60 min reduced static CO_2 accumulation and improved the intensities of desirable flavor attributes. Due to cantaloupe's thick skin and short treatment time, heat used in the present study did not penetrate deep into the flesh of the melons used for preparation of fresh-cut fruit (Solomon and others 2006), which may explain why hot water did not change O_2 and CO_2 levels. The O_2 levels in the clamshell containers often dropped below 3% while CO_2 increased to more than 15% after 10-d storage. It is recommended that cut cantaloupes be stored in 3% to 6% O_2 and 6% to 15% CO_2 at 0 to 5 °C to avoid injury and off-flavors caused by anaerobic respiration (Gorny 1997). Ethanol levels, an end product of anaerobic metabolism in cut cantaloupes, increased linearly during storage in 1.5% and 3% O_2 at 5 °C (Portela and others 1997), suggesting that fresh-cut cantaloupes are susceptible to low oxygen injury. Our earlier results (Fan and others 2006) showed that low levels (2% to 3%) of CO_2 accumulated in packages, and O_2 levels were maintained more than 16% during 7-d storage at 4 °C. Even though the packaging materials used in both studies were polystyrene, the containers used in the present study were much tighter (judged by the difficulty of opening and closing the containers) than those in the previous study (Fan and others 2006), which may restrict gas exchanges.

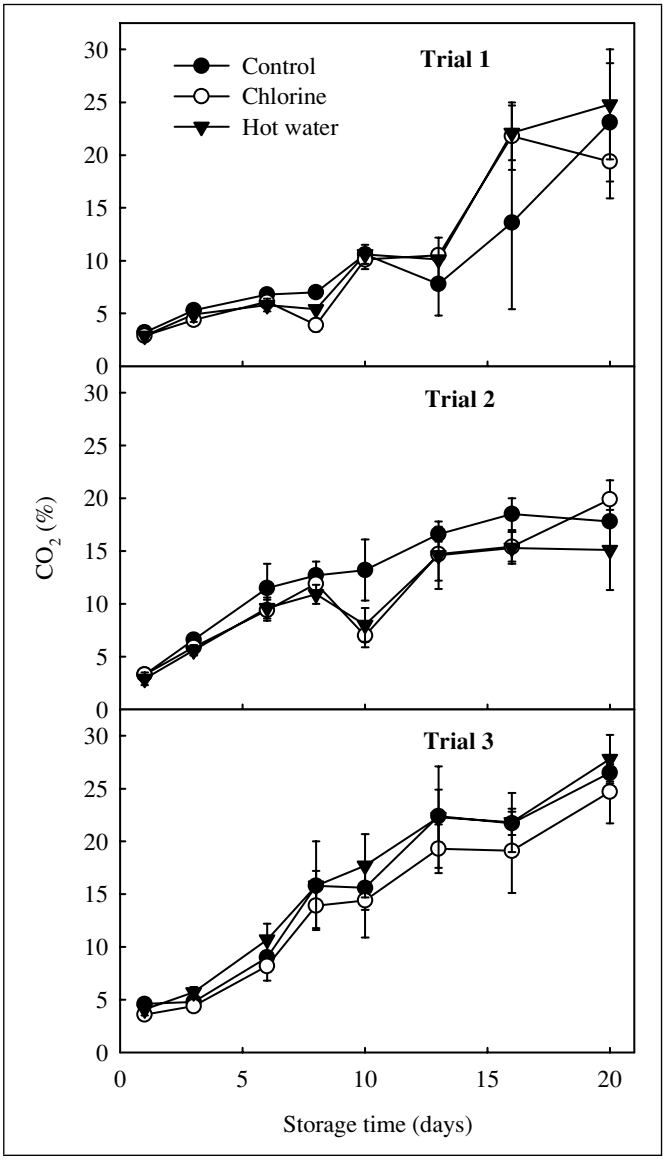

Figure 2—Effects of hot water and chlorine treatment of whole cantaloupes on headspace CO_2 levels in the packages of fresh-cut fruit during storage at 4 °C. Vertical bars represent standard deviations of means (n = 3).

Microbial population on the surface of whole cantaloupes

Compared to unwashed controls, neither cold water nor chlorine significantly affected the TPC on the rind of cantaloupes in any of the trials (Table 1). Similarly, cold water did not reduce yeast and mold count in any trial. Chlorine reduced yeast and mold only in 1 of the 3 trials. Hot water treatment consistently reduced TPC and mold and yeast count in all 3 trials. Compared to the unwashed controls, hot water reduced TPC by at least 1 log and yeast and mold count by at least 2 log. It appears that the hot water treatment was more effective in reducing mold and yeast than bacteria on whole cantaloupes. The hot water treatment resulted in 5-log reduction of artificially inoculated *Salmonella* on whole cantaloupe in a previous study (Annous and others 2004), but was only able to reduce TPC by 1 to 2 logs. Compared to the artificially inoculated *Salmonella*, native microflora may occupy more protective microniches, such as within the netting, thereby rendering them more resistant to heat.

Microbial populations on the fresh-cut fruit during storage

Initially, TPC of fresh-cut cantaloupes was low regardless of treatments (Table 2). Chlorine treatment of whole cantaloupe did not result in significantly lower TPC on fresh-cut pieces prepared from the treated fruit in any of the trials. It is not a surprise that chlorine treatments of whole cantaloupe had no significant effect on TPC of fresh-cut pieces since chlorine had no effect on TPC on the whole cantaloupes. Even though the hot water treatments of whole cantaloupe lowered TPC on whole cantaloupe, TPC of fresh-cut pieces from the hot water-treated fruits was similar to that of fresh-cut pieces from the control or chlorine-treated fruits initially. However, the fresh-cut pieces from hot water-treated cantaloupes often had significantly lower TPC populations as compared with

Table 1—The effect of hot water surface pasteurization on total plate count (TPC) and yeast and mold count (log CFU/cm²) on the rinds of the whole cantaloupes.

	Trial 1		Trial 2		Trial 3	
Treatments	TPC	Molds and yeast	TPC	Molds and yeast	TPC	Molds and yeast
Unwashed control	5.3 ± 0.7 a[a]	4.2 ± 0.1 a	5.4 ± 0.4 a	4.4 ± 0.4 a	4.6 ± 0.2 ab	4.9 ± 0.1 a
Cold water control	5.1 ± 0.6 a	3.9 ± 0.2 ab	5.0 ± 0.3 ab	4.1 ± 0.1 a	5.1 ± 0.7 a	4.9 ± 0.3 a
Chlorine	4.5 ± 0.2 ab	3.1 ± 0.1 bc	5.0 ± 0.9 ab	3.7 ± 0.7 a	4.8 ± 1.1 ab	4.3 ± 0.3 a
Hot water	3.9 ± 0.2 b	1.9 ± 0.8 c	4.3 ± 0.2 b	1.3 ± 0.8 b	3.6 ± 0.4 b	1.3 ± 0.5 b

[a]Means with same letters within the same columns are not significantly different ($P > 0.05$).

Table 2—The effect of hot water pasteurization of whole cantaloupe on total plate count (log CFU/g) of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	2.9 ± 0.6 a[a]	3.2 ± 0.6 a	3.9 ± 0.6 a
6	3.3 ± 0.6 a	3.4 ± 0.7 a	3.4 ± 0.8 a
8	3.1 ± 0.4 a	3.3 ± 0.6 a	3.4 ± 0.2 a
10	3.4 ± 0.5 a	3.1 ± 0.0 a	3.4 ± 0.5 a
13	3.3 ± 0.3 a	3.0 ± 0.4 a	3.8 ± 0.6 a
16	3.5 ± 0.5 a	3.5 ± 0.4 a	3.6 ± 0.8 a
20	4.2 ± 0.4 a	3.6 ± 0.2 b	3.8 ± 0.4 ab
LSD[b]	0.9	0.8	1.0
Trial 2			
1	3.1 ± 0.6 a	2.9 ± 0.7 a	2.9 ± 0.6 a
6	3.8 ± 0.8 a	3.5 ± 0.3 ab	2.3 ± 0.7 b
8	4.2 ± 0.6 a	4.3 ± 0.2 a	3.9 ± 0.5 a
10	4.9 ± 0.5 a	4.8 ± 0.7 a	2.9 ± 0.8 b
13	6.3 ± 0.7 a	5.6 ± 0.8 a	3.6 ± 0.3 b
16	6.9 ± 0.7 a	6.9 ± 0.7 a	2.8 ± 0.3 b
20	7.9 ± 0.7 a	7.8 ± 0.7 a	5.0 ± 1.3 b
LSD	1.1	1.1	1.2
Trial 3			
1	2.8 ± 1.0 a	2.6 ± 0.9 a	3.2 ± 1.7 a
6	4.3 ± 0.8 a	3.9 ± 1.1 a	2.4 ± 2.1 a
8	4.8 ± 0.9 a	4.9 ± 2.2 a	3.0 ± 0.6 a
10	5.8 ± 0.9 a	6.0 ± 2.4 a	2.7 ± 2.0 a
13	7.3 ± 0.5 a	6.5 ± 1.6 a	3.2 ± 0.8 b
16	7.4 ± 0.5 a	7.4 ± 0.8 a	3.8 ± 0.4 b
20	8.0 ± 0.6 a	7.3 ± 0.5 ab	4.6 ± 2.8 b
LSD	1.4	2.5	2.8

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

Table 3—The effect of hot water pasteurization of whole cantaloupe on yeast and mold population (log CFU/g) of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	2.2 ± 0.8 a[a]	2.1 ± 0.8 a	2.5 ± 0.9 a
6	2.0 ± 0.3 a	2.5 ± 0.2 a	1.9 ± 1.0 a
8	2.3 ± 0.3 a	2.6 ± 0.7 a	1.7 ± 1.0 a
10	2.7 ± 1.0 a	2.5 ± 0.7 a	2.3 ± 0.7 a
13	2.0 ± 0.2 a	2.0 ± 0.4 a	2.2 ± 0.2 a
16	2.2 ± 0.5 a	2.6 ± 0.3 a	2.7 ± 0.3 a
20	3.2 ± 0.4 a	2.4 ± 0.8 a	2.3 ± 0.5 a
LSD[b]	1.0	1.0	1.3
Trial 2			
1	2.3 ± 0.8 a	1.9 ± 0.8 a	2.2 ± 0.2 a
6	2.8 ± 0.5 a	2.0 ± 0.7 ab	0.9 ± 1.1 b
8	2.6 ± 0.5 a	2.3 ± 0.2 a	1.7 ± 1.1 a
10	2.7 ± 0.7 a	2.2 ± 0.2 ab	1.1 ± 0.7 b
13	2.9 ± 1.3 a	1.4 ± 0.7 a	1.3 ± 0.3 a
16	3.2 ± 0.4 a	1.8 ± 1.0 a	1.7 ± 0.9 a
20	3.4 ± 1.3 a	2.2 ± 0.6 a	1.9 ± 0.9 a
LSD	1.5	1.1	1.4
Trial 3			
1	2.0 ± 1.4 a	1.9 ± 0.8 a	1.5 ± 1.2 a
6	3.0 ± 0.3 a	2.7 ± 0.6 a	2.1 ± 1.0 a
8	2.7 ± 0.6 a	2.9 ± 0.4 a	1.9 ± 1.5 a
10	3.5 ± 0.7ab	4.0 ± 0.5 a	2.2 ± 1.0 b
13	3.3 ± 0.3 a	3.6 ± 0.4 a	1.5 ± 1.5 b
16	3.0 ± 0.9 a	3.2 ± 0.9 a	1.7 ± 1.1 a
20	3.6 ± 0.8 ab	3.8 ± 1.3 a	1.1 ± 1.7 b
LSD	1.3	1.2	2.1

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

pieces from the control or chlorine-treated fruit during the latter period of 20-d storage. The differences were more pronounced toward the end of the storage. It is possible that hot water injured bacteria, and the injured bacteria did not grow or grew slower than the controls during storage.

Yeast and mold count did not significantly increase during storage for any of the treatments (Table 3). Similar to TPC, chlorine treatment of whole fruits did not result in lower yeast and mold population on the fresh-cut pieces compared with the control. Although hot water consistently reduced yeast and mold count on the whole cantaloupes, the fresh-cut fruits prepared from the cantaloupes did not always have lower yeast and mold count than the control. Compared with the control, significant reduction of yeast and mold count on fresh-cut pieces from hot water-treated fruits were observed only in some of the storage days in 2 of 3 trials.

Our results showed that the CO_2 levels reached more than 15% in the containers in the later storage period. However, bacteria and yeast and molds continued to grow in some of the samples. Many studies demonstrate that CO_2 inhibited microbial growth and prolonged the lag phase (Werner and Hotchkiss 2005). It has been shown that the combination of low O_2 and high CO_2 levels is able to maintain a low microbial population and extend shelf life of fresh-cut cantaloupes (O'Connor-Shaw and others 1996; Portela and others 1997). Gunes and Hotchkiss (2002) showed that high CO_2 levels ($\geq$ 15%) inhibited not only the growth of *E. coli* O157:H7 but also yeast and other fungal growth on apple slices. Niemira and others (2005) showed modified atmosphere packaging inhibited the growth of *Listeria monocytogenes* in fresh-cut endive.

Sensory quality

Neither chlorine nor hot water treatments of whole cantaloupes had a consistent effect on appearance or aroma scores of fresh-cut pieces prepared from the treated fruit (Table 4 and 5). Both appearance and aroma scores of all samples decreased during storage. The declines in the appearance scores were primarily caused by soggy edges and slight dehydration. No sign of microbial decay was found. The defects in aroma were mostly due to the diminution of characteristic melon smell and the development of off-odors (musty and sulfur). Musty and off-odors were observed in fresh-cuts prepared at various maturities and stored up to 14 d under optimal temperature (4 °C) (Bett-Garber and others 2003; Beaulieu and others 2004).

Soluble solids content, texture, ascorbic acid, and fluid loss

Soluble solids contents of fresh-cut cantaloupes were not affected by any of the treatments during the entire storage period for all 3 trials (data not shown). In our previous study (Fan and others 2006), a slightly lower SSC was observed for samples from hot water-treated fruit than the control.

Compared to the controls, hot water treatment had no effect on firmness in the 1st 2 trials (Table 6). In trial 3, samples from hot water-treated fruit had higher firmness than the control at days 1 and 6. Samples prepared from chlorine-treated cantaloupes had significantly higher firmness than the control at day 16 in trial 1, at days 1 and 20 in trial 2, and at days 1, 6, 8, 10, and 20 in trial 3. Taking all 3 trials together, samples from chlorine-treated fruit had significantly ($P < 0.05$) higher firmness than the control.

In trial 1, ascorbic acid content was not significantly affected by any treatment, except pieces from chorine-treated cantaloupes had significantly higher ascorbic acid content than the control and those from hot water fruit at day 6 (Table 7). In trial 2, samples from hot water-treated fruit had lower ascorbic acid content than the control at days 1 and 8 while samples from chlorine-treated fruit had lower ascorbic acid content than the control at day 13. In other sampling days, ascorbic acid content was similar for the 3 treatments. Ascorbic acid content was not affected by any treatment at trial 3. During storage, ascorbic acid content did not change appreciably. A recent study (Gil and others 2006) has shown that ascorbic acid content was maintained in fresh-cut fruits during storage and fresh-cut fruits visually spoiled before any significant nutrient loss occurred.

Fluid loss increased significantly for all treatments during storage in the 1st 2 trials, but not for the control and samples prepared

Table 5—The effect of hot water pasteurization of whole cantaloupe on aroma score of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	8.2 ± 0.3 a[a]	8.1 ± 0.1 a	8.4 ± 0.1 a
6	6.9 ± 0.5 a	7.0 ± 0.4 a	7.3 ± 0.7 a
8	6.7 ± 0.3 a	6.4 ± 0.6 a	7.1 ± 0.2 a
10	5.8 ± 0.2 a	6.3 ± 0.4 a	6.1 ± 0.4 a
13	5.5 ± 0.4 a	4.8 ± 1.2 a	5.6 ± 1.4 a
16	4.5 ± 0.2 a	4.7 ± 0.7 a	4.1 ± 0.5 a
20	4.0 ± 0.3 b	5.1 ± 0.2 a	4.0 ± 0.0 b
LSD[b]	0.6	1.0	1.1
Trial 2			
1	8.5 ± 0.3 a	8.2 ± 0.5 a	8.6 ± 0.1 a
6	8.2 ± 0.3 a	7.4 ± 0.4 b	7.8 ± 0.2 ab
8	7.3 ± 0.2 b	7.1 ± 0.2 b	7.8 ± 0.0 a
10	6.8 ± 0.3 a	6.5 ± 0.3 a	6.5 ± 0.4 a
13	5.9 ± 0.5 a	5.7 ± 0.6 a	6.1 ± 0.8 a
16	4.7 ± 0.4 a	4.8 ± 1.4 a	5.4 ± 0.3 a
20	2.2 ± 0.5 b	2.1 ± 0.7 b	4.6 ± 0.5 a
LSD	0.6	1.2	0.7
Trial 3			
1	7.7 ± 0.6 a	8.1 ± 0.3 a	8.2 ± 0.4 a
6	6.8 ± 0.7 a	7.3 ± 0.3 a	6.8 ± 0.7 a
8	6.9 ± 1.0 a	6.8 ± 0.3 a	6.9 ± 0.7 a
10	6.5 ± 0.6 a	5.9 ± 0.7 a	6.3 ± 0.6 a
13	5.7 ± 0.8 a	5.3 ± 0.7 a	5.2 ± 0.2 a
16	4.6 ± 0.3 a	5.3 ± 0.5 a	4.9 ± 0.5 a
20	3.8 ± 1.3 a	3.8 ± 0.7 a	4.2 ± 0.8 a
LSD	1.4	0.9	1.0

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

Table 4—The effect of hot water pasteurization of whole cantaloupe on appearance score of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	7.9 ± 0.3 a[a]	8.2 ± 0.2 a	8.2 ± 0.3 a
6	7.1 ± 0.3 b	7.7 ± 0.2 a	8.0 ± 0.3 a
8	6.8 ± 0.5 b	7.4 ± 0.2 ab	7.5 ± 0.2 a
10	6.2 ± 0.4 b	7.2 ± 0.2 a	6.7 ± 0.1 a
13	5.9 ± 0.4 a	6.2 ± 0.4 a	6.4 ± 0.1 a
16	5.6 ± 0.1 a	5.9 ± 0.4 a	6.0 ± 0.5 a
20	4.0 ± 0.0 c	5.4 ± 0.1 a	4.4 ± 0.1 b
LSD[b]	0.6	0.4	0.4
Trial 2			
1	8.3 ± 0.0 a	8.5 ± 0.4 a	8.6 ± 0.2 a
6	7.9 ± 0.1 a	7.9 ± 0.1 a	7.9 ± 0.2 a
8	7.5 ± 0.2 a	7.6 ± 0.3 a	7.8 ± 0.2 a
10	7.1 ± 0.2 b	7.7 ± 0.3 a	7.3 ± 0.3 ab
13	6.8 ± 0.3 a	6.8 ± 0.2 a	6.9 ± 0.3 a
16	5.9 ± 0.2 a	6.3 ± 0.6 a	6.4 ± 0.2 a
20	4.9 ± 0.2 a	5.1 ± 0.1 a	5.3 ± 0.3 a
LSD	0.3	0.6	0.4
Trial 3			
1	8.5 ± 0.2 a	8.7 ± 0.0 a	8.7 ± 0.0 a
6	7.9 ± 0.2 a	7.9 ± 0.1 a	8.1 ± 0.4 a
8	7.4 ± 0.1 a	7.5 ± 0.2 a	7.8 ± 0.3 a
10	7.1 ± 0.3 a	7.1 ± 0.3 a	7.3 ± 0.2 a
13	6.2 ± 0.1 b	6.4 ± 0.3 b	6.8 ± 0.2 a
16	5.1 ± 0.3 a	5.5 ± 0.3 a	5.5 ± 0.2 a
20	4.9 ± 0.5 a	5.4 ± 0.4 a	4.9 ± 0.1 a
LSD	0.5	0.4	0.4

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

Table 6—The effect of hot water pasteurization of whole cantaloupe on texture (force, *N*) of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	1296 ± 548 a[a]	1403 ± 790 a	1337 ± 492 a
6	1070 ± 433 a	1274 ± 409 a	1150 ± 433 a
8	1218 ± 374 a	1164 ± 548 a	1235 ± 581 a
10	1095 ± 546 a	1464 ± 504 a	1239 ± 608 a
13	1258 ± 399 a	1480 ± 545 a	1119 ± 496 a
16	991 ± 500 b	1464 ± 380 a	1330 ± 502 ab
20	1200 ± 359 a	1513 ± 731 a	1292 ± 500 a
LSD[b]	372	468	422
Trial 2			
1	1129 ± 465 b	1553 ± 512 a	1203 ± 541 ab
6	1195 ± 470 a	1448 ± 480 a	1301 ± 462 a
8	1468 ± 386 a	1223 ± 359 a	1304 ± 554 a
10	1478 ± 634 a	1368 ± 318 a	1227 ± 555 a
13	1352 ± 444 a	1355 ± 435 a	1269 ± 455 a
16	1376 ± 393 a	1523 ± 346 a	1509 ± 353 a
20	1167 ± 461 b	1596 ± 433 a	1279 ± 608 ab
LSD	382	339	415
Trial 3			
1	1680 ± 231 b	1898 ± 141 a	1834 ± 147 a
6	1489 ± 228 b	1768 ± 261 a	1741 ± 303 a
8	1632 ± 272 b	1862 ± 174 a	1528 ± 254 b
10	1560 ± 238 b	1836 ± 263 a	1563 ± 205 b
13	1551 ± 352 a	1650 ± 172 a	1474 ± 278 a
16	1491 ± 301 a	1628 ± 239 a	1496 ± 178 a
20	1467 ± 177 b	1748 ± 155 a	1518 ± 267 b
LSD	213	138	194

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

Table 7—The effect of hot water pasteurization of whole cantaloupe on ascorbic acid (μg/g) of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	282 ± 43 a[a]	273 ± 54 a	293 ± 25 a
6	282 ± 12 b	349 ± 37 a	279 ± 30 b
8	239 ± 29 a	247 ± 50 a	299 ± 14 a
10	245 ± 49 a	265 ± 41 a	289 ± 39 a
13	244 ± 25 a	251 ± 43 a	311 ± 68 a
16	269 ± 10 a	280 ± 23 a	270 ± 17 a
20	264 ± 33 a	278 ± 50 a	292 ± 49 a
LSD[b]	56	77	68
Trial 2			
1	305 ± 22 a	283 ± 35 ab	239 ± 24 b
6	293 ± 22 a	310 ± 26 a	290 ± 30 a
8	305 ± 31 a	275 ± 4 ab	231 ± 43 b
10	251 ± 33 a	259 ± 42 a	276 ± 40 a
13	309 ± 21 a	222 ± 49 b	259 ± 16 ab
16	300 ± 37 a	314 ± 42 a	287 ± 26 a
20	256 ± 13 a	290 ± 20 a	235 ± 51 a
LSD	48	60	61
Trial 3			
1	264 ± 46 a	251 ± 9 a	255 ± 36 a
6	283 ± 44 a	243 ± 47 a	210 ± 92 a
8	271 ± 34 a	253 ± 44 a	243 ± 38 a
10	245 ± 43 a	255 ± 49 a	272 ± 30 a
13	264 ± 69 a	290 ± 20 a	281 ± 20 a
16	273 ± 24 a	206 ± 30 a	249 ± 46 a
20	239 ± 27 a	209 ± 11 a	228 ± 2 a
LSD	76	59	80

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

Table 8—The effect of hot water pasteurization of whole cantaloupe on color (L^*) of fresh-cut cantaloupes stored at 4 °C.

Storage time (d)	Treatments		
	Cold water control	Chlorine	Hot water
Trial 1			
1	57.3 ± 4.5 b[a]	62.1 ± 3.1 a	61.0 ± 2.6 a
6	61.3 ± 3.9 b	63.2 ± 2.4 a	64.0 ± 2.7 a
8	55.2 ± 5.0 b	62.4 ± 3.0 a	61.1 ± 3.5 a
10	58.4 ± 3.7 c	64.1 ± 2.4 a	61.6 ± 2.2 b
13	58.6 ± 5.7 b	63.6 ± 1.9 a	63.3 ± 3.1 a
16	59.6 ± 3.1 b	65.3 ± 2.4 a	63.8 ± 2.8 a
20	58.8 ± 3.0 c	64.9 ± 2.3 a	62.3 ± 2.0 b
LSD[b]	2.4	1.5	1.6
Trial 2			
1	68.8 ± 2.7 b	68.9 ± 2.2 b	70.7 ± 2.5 a
6	65.5 ± 2.0 ab	64.0 ± 1.7 b	65.7 ± 1.9 a
8	65.5 ± 2.2 a	65.8 ± 1.4 a	64.9 ± 1.8 a
10	65.5 ± 2.1 a	65.3 ± 1.5 a	66.3 ± 1.9 a
13	66.4 ± 2.0 a	65.2 ± 1.8 b	66.6 ± 2.0 a
16	65.4 ± 1.8 b	65.1 ± 1.3 b	66.8 ± 1.7 a
20	63.2 ± 2.1 b	63.4 ± 1.9 b	65.5 ± 1.9 a
LSD[b]	1.2	1.5	1.4
Trial 3			
1	65.3 ± 2.1 b	66.7 ± 1.8 a	66.5 ± 1.4 a
6	65.9 ± 1.8 a	66.6 ± 2.4 a	65.8 ± 1.9 a
8	66.7 ± 2.1 a	66.7 ± 1.9 a	66.0 ± 2.0 a
10	64.0 ± 2.8 b	65.5 ± 1.8 a	65.5 ± 1.9 a
13	66.2 ± 1.8 b	68.8 ± 2.1 a	67.8 ± 1.8 a
16	66.9 ± 2.5 b	67.5 ± 2.0 a	66.5 ± 2.3 a
20	66.2 ± 3.1 b	67.8 ± 1.4 a	65.3 ± 2.6 b
LSD	1.3	1.1	1.2

[a]Means with same letters within the same rows are not significantly different ($P > 0.05$).
[b]The least significant difference at $P < 0.05$ levels for the storage effect.

from chlorine-treated fruit in the 3rd trial (data not shown). The fruits in the 3rd trial were much firmer than those in 1st and 2nd trials (Table 6), which may explain no change in fluid loss during storage observed in the 3rd trial. The fluid loss was not affected by any treatment in any of 3 trials.

Color

In trial 1, samples from hot water- and chlorine-treated fruit always had higher L^* values than the control, indicating that those 2 samples were darker than the control (Table 8). In trial 2, L^* values were mostly similar among the 3 treatments during the 20-d storage at 4 °C. In trial 3, samples from hot water-treated fruit had higher L^* values than the control at days 1, 10, 13, and 16 while samples from chlorine-treated fruit had higher L^* values than the control at days 1, 10, 13, 16, and 20. Even though the instrumental measurement of color indicated that samples from hot water- and chlorine-treated cantaloupes were darker (higher L^* values) in some storage times, sensory evaluation did not reveal any visible color difference among the 3 treatments.

Samples from hot water- and chlorine-treated fruit had similar hue or chroma values compared to the control in any of the trials (data not shown).

Yeast and molds are mostly responsible for decay in many fresh-cut fruits (Ngarmsak and others 2006). Surprisingly, the fresh-cut cantaloupes held up well in the present study. Our results indicate that the fresh-cut fruits could be kept for at least 13 d, irrespective of the treatments. Perhaps the high CO_2 and low O_2 levels in the packages contributed to the preservation of the products. Modified atmosphere has been shown to inhibit yeast growth and maintain or improve shelf life and quality of fresh-cut produce (Jacxsens and others 2001; Rattanapanone and others 2001). O'Connor-Shaw and others (1996) suggested that surface sterilized cantaloupe pieces could be stored for up to 28 d in controlled atmosphere of 6% to 15% CO_2 and 3.5% to 5% O_2 at 4.5 °C without significant loss of quality. Ayhan and Chism (1998) found that sterilized (using high-level NaOCl) fresh-cut cantaloupes stored at 5% O_2 and 2 °C had a shelf life of 15 d.

Conclusions

Our results indicated that hot water pasteurization of whole cantaloupes reduced TPC and yeast and mold count on the whole cantaloupe. The treatment also frequently resulted in lower TPCs on fresh-cut fruit. Chlorine treatment did not reduce TPC or yeast and mold on the whole or fresh-cut cantaloupes. Despite the lower TPC and occasionally lower yeast and mold count on the fresh-cut fruit prepared from the hot water-treated cantaloupes, better aroma and appearance were not always observed. Hot water did not have any negative effect on quality attributes. Overall, hot water treatment of whole fruit was superior to chlorine in reducing microbial population of both whole and fresh-cut cantaloupes.

Acknowledgments

The authors wish to thank Kimberly Sokorai, Angela Burke, Lumei Cheung, and Andrew Bigley for technical support.

References

Aguayo E, Escalona VH, Artes F. 2004. Metabolic behavior and quality changes of whole and fresh processed melon. J Food Sci 69:SNG148–55.
Annous BA, Burke A, Sites JE. 2004. Surface pasteurization of whole fresh cantaloupes inoculated with *Salmonella poona* or *Escherichia coli*. J Food Prot 67:1876–85.
Ayhan Z, Chism GW. 1998. The shelf-life of minimally processed fresh-cut melons. J Food Qual 21:29–40.
Bai JH, Saftner RA, Watada AE, Lee YS. 2001. Modified atmosphere maintains quality of fresh-cut cantaloupe (*Cucumis melo* L.). J Food Sci 8:1207–11.

Beaulieu JC. 2005. Within-season volatile and quality differences in stored fresh-cut cantaloupe cultivars. J Agric Food Chem 53(22):8679–87.
Beaulieu JC, Lea JM. 2003. Aroma volatile differences in commercial orange-fleshed cantaloupes, the inbred parental lines, and stored fresh-cuts. Acta Hort 628: 809–15.
Beaulieu JC, Ingram DA, Lea JM, Bett-Garber KL. 2004. Effect of harvest maturity on the sensory characteristics of fresh-cut cantaloupe. J Food Sci 69:S250–8.
Bett-Garber KL, Beaulieu JC, Ingram DA. 2003. Effect of storage on sensory properties of fresh-cut cantaloupe varieties. J Food Qual 26(4):323–35.
Boynton BB, Welt BA, Sims CA, Balaban MO, Brecht JK, Marshall MR. 2006. Effects of low-dose electron beam irradiation on respiration, microbiology, texture, color, and sensory characteristics of fresh-cut cantaloupe stored in modified-atmosphere packages. J Food Sci 71:S149–55.
Fan X, Toivonen PMA, Rajkowski KT, Sokorai K. 2003. Warm water treatment in combination with modified atmosphere packaging reduced undesirable effects of irradiation on the quality of fresh-cut iceberg lettuce. J Agric Food Chem 51:1231–6.
Fan X, Niemera BA, Mattheis JP, Zhuang H, Olson DW. 2005. Quality of fresh-cut apple slices as affected by low dose ionizing radiation and calcium ascorbate treatment. J Food Sci 70:S143–8.
Fan X, Annous BA, Sokorai KJ, Burke AM, Mattheis JP. 2006. Combination of hot water surface pasteurization of whole fruit and low dose irradiation of fresh-cut cantaloupe. J Food Prot 69:912–9.
[USFDA] U.S. Food and Drug Administration. 2001a. Program information manual. Available from: http://www.cfsan.fda.gov/~ear/ret-mln.html. Accessed Nov 4, 2006.
[USFDA] U.S. Food and Drug Administration. 2001b. FDA survey of imported fresh produce: program information manual. Available from: http://www.cfsan.fda.gov/~dms/prodsur6.html. Accessed Nov 4, 2006.
[USFDA] U.S. Food and Drug Administration. 2003. FDA Survey of domestic fresh produce. Available from: http://www.cfsan.fda.gov/~dms/prodsu10.html. Accessed Nov 4, 2006.
Gil MI, Aguayo E, Kader AA. 2006. Quality changes and nutrient retention in fresh-cut versus whole fruits during storage. J Agric Food Chem 54(12):4284–96.
Gorny JR. 1997. A summary of CA and MA requirements and recommendations for fresh-cut fruits and vegetables. In: Gorny JR, editor. Proc. 7th Controlled Atmosphere Res Conf. Vol. 5. Davis, Calif.: Univ. of California. p 30–66.
Graham WD, Annette D.1992. Determination of ascorbic and dehydroascorbic acid in potatoes (*Solanum tuberosum*) and strawberries using ion-exclusion chromatography. J Chromatogr 594:187–94.
Gunes GG, Hotchkiss JH. 2002. Growth and survival of *Escherichia coli* O157:H7 on fresh-cut apples in modified atmospheres at abusive temperatures. J. Food Protect 65(10):1641–5.
Jacxsens L, Devlieghere F, Steen C, van der Debevere J. 2001. Effect of high oxygen modified atmosphere packaging on microbial growth and sensorial qualities of fresh-cut produce. Int J Food Microbiol 71(2/3):197–210.
Lamikanra O, Bett Garber KL, Ingram DA, Watson MA. 2005. Use of mild heat pretreatment for quality retention of fresh-cut cantaloupe melon. J Food Sci 70: C53–7.
Luna-Guzman I, Barrett DM. 2000. Comparison of calcium chloride and calcium lactate effectiveness in maintaining shelf stability and quality of fresh-cut cantaloupes. Postharvest Biol Technol 19(1):61–72.
Lurie S. 1998. Postharvest heat treatments of horticultural crops. Hortic Rev 22:91–121.
Ngarmsak M, Delaquis P, Toivonen P, Ngarmsak T, Ooraikul B, Mazza G. 2006. Microbiology of fresh-cut mangoes prepared from fruit sanitized in hot chlorinated water. Food Sci Technol Int 12:95–102.
Niemira BA, Fan X, Sokorai KJ. 2005. Irradiation and modified atmosphere packaging of endive influences survival and regrowth of *Listeria monocytogenes* and product sensory qualities. J Rad Phys Chem 72:41–8.
O'Connor-Shaw RE, Roberts R, Ford AL, Nottingham SM. 1996. Changes in sensory quality of sterile cantaloupe dice stored in controlled atmosphere. J Food Sci 61:847–51.
Paull RE, Chen NJ. 2000. Heat treatment and fruit ripening. Postharvest Biol Technol 21:21–37.
Portela S, Nie X, Suslow T, Cantwell M. 1997. Changes in sensory quality and fermentative volatile concentrations of minimally processed cantaloupe stored in controlled atmospheres. In: Gorny JR, editor. Proc. 7th Controlled Atmosphere Res Conf. Vol. 5, Davis, Calif.: Univ. of California. p 123–9.
Rattanapanone N, Lee Y, Wu T, Watada AE. 2001. Quality and microbial changes of fresh-cut mango cubes held in controlled atmosphere. HortScience 36(6):1091–5.
Sapers GM, Miller RL, Pilizota V, Mattrazzo AM. 2001. Antimicrobial treatments for minimally processed cantaloupe melon. J Food Sci 66:345–9.
Smith M. 2006. Promoting produce food safety and defense. Institute of Food Technologist Annual Meeting, Abstract nr 026–06.
Solomon EB, Huang L, Sites JE, Annous BA. 2006. Thermal inactivation of *Salmonella* on cantaloupes using hot water. J Food Sci 71(2):M25–30.
Ukuku DO, Fett WF, Sapers GM. 2004a. Inhibition of *Listeria monocytogenes* by native microflora of whole cantaloupe. J Food Saf 24:129–46.
Ukuku DO, Pilizota V, Sapers GM. 2004b. Effect of hot water and hydrogen peroxide treatment on survival of *Salmonella* and microbial quality of whole cantaloupe and fresh-cut cantaloupe. J Food Prot 67:432–7.
Werner BG, Hotchkiss JH. 2005. Modified atmosphere packaging. In: Sapers GM, Gorny JR, Yousef AE, editors. Microbiology of fruits and vegetables. Boca Raton, Fla.: CRC Press. p 437–59.